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the PROBLEM of LARGE-AREA PLUTONIUM CONTAMINATION

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SELECTED PAPERS from the BUREAU of RADIOLOGICAL HEALTH SEMINAR PROGRAM

The Bureau of Radiological Health (BRH) Seminar Program is an outgrowth of several seminar program efforts conducted within the Bureau. The X-Ray Exposure Control Laboratory (XECL), the Radiation Bio-Effects Program, and the Research Grants Section had each established effective programs for the purpose of disseminating information. In 1968 these programs were combined into the Bureau of Radiological Health Seminar Program to encompass the total range of radiological health activities engaged in by the BRH.

The papers published in this series were originally oral presentations made at the XECL Seminar Program or at the BRH Seminar Program.

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Dr. Wright H. Langham has been associated with the atomic energy developmental program for nearly 25 years. The first two years were spent at the Metallurgical Laboratory of the University of Chicago and at Los Alamos developing micromethods for the analysis of trace impurities in plutonium.

In late 1945, his interests were turned to problems of toxiocology, biophysics, and radiobiology. He became the Group Leader of the Biomedical Research Group of the Los Alamos Scientific Laboratory in 1946 and still holds that position. His major interests have been in the fields of physiology and toxicology of plutonium, tritium, and other radioactive materials; radiation effects of nuclear weapons; effects of massive doses of radiation on animals; relative biological effectiveness of radiation of different types and different energies; potential hazards of world-wide radioactive fallout from nuclear weapons tests; use of radioisotopes in biology and medicine; and radiation problems associated with space conquest. He has authored or co-authored some 150 to 200 papers and reports on various aspects of the nuclear energy program.

He was formerly a member of the International Subcommittee on Internal Hazards of Radiation and the National Committee for Radiation Protection. He was chairman of the Radiobiology Study Panel of the NAS/NRC Space Science Board and editor of the Panel's recent report on "Radiobiological Factors in Manned Space Flight." Dr. Langham is currently president of the Health Physics Society; a member of the World Health Organization Expert Advisory Panel on Radiation, the Radiation Research Society, and the Federation of American Societies for Experimental Biology. He has served as consultant to the Surgeon General of the Army and was recipient of the American Medical Association's special Aerospace Medicine Honor Citation. In 1967, he was awarded the Department of Defense Distinguished Service Medal for his service to the United States and Spanish governments in relation to the nuclear weapons accident in Spain.

He obtained a B.S. degree from the Oklahoma A and M College (Goodwell), M.S. degree from Oklahoma State University (Stillwater), and a Ph.D. degree from the University of Colorado.

THE PROBLEM OF LARGE-AREA PLUTONIUM CONTAMINATION

Wright H. Langham, Ph.D.

INTRODUCTION

Although no plutonium contamination incidents have occurred within the public domain that have imposed serious risk on a population group, the probability that such might occur is likely to increase with the current increasing trends in production and use of plutonium isotopes. Plutonium is my favorite element for both objective and personal reasons. Plutonium currently is the most uniquely useful substance to come from alchemist Seaborg's works and dreams. Plutonium-239 (half-life 24,400 years) was the fissionable material that ushered in a new era in weaponry with the detonation of the first atomic bomb on July 16, 1945, near Alamogordo, New Mexico. It still is used extensively in present day fusion weapons systems. Although this use may be of negative aesthetic value, it nevertheless is a reality. On the positive side is the great potential of ^{239}Pu as a reactor fuel in "breeder" reactor concepts. In addition, because of its abundance, it is used extensively as a starting material for the production of transuranic elements of greater mass number. Plutonium-238 (half-life 90 years) is one of the most practical radionuclides for radioisotopic power generators. Such light-weight, dependable power sources are already finding space and terrestial applications. The first power station this country plans to operate on the moon will be a ^{238}Pu thermoelectric generator. Equally as exciting is the potential of ^{238}Pu power sources for human implantation. Such sources are already being developed to power circulatory support systems, including a complete mechanical heart. These represent a few of the objective reasons why plutonium is my favorite element. There are two very good personal reasons. Upon completing my schooling in the spring of 1943, I was given the choice of joining the Manhattan Project at the University of Chicago to work on plutonium (revealed later) or accepting a 1-A draft card. With my physical qualifications, this personally was probably a very fortunate incident both for me and for the armed services. Since that time the reputation of plutonium as a toxic material perhaps has contributed more than any other thing to my being supported in the modest though comfortable manner to which I have grown accustomed.

Every technical advancement has associated with it its own specific element of risk; in this regard, plutonium is no exception. Because of its toxic properties, it is a potential health hazard to those who work with it, and its accidental dispersal in the public domain would impose an element of risk on the inhabitants of the contaminated area. Not only would there be an element of risk during dispersal and deposition of the contamination, but supposedly there would be a residual risk associated with occupancy of the area for an unknown period afterward.

Conceivably, dispersal of plutonium in the public domain could result from accidents involving transportation, storage, and deployment of nuclear weapons, fires in plutonium processing areas, launch pad explosions, flight aborts and reentry of space vehicles carrying thermoelectric generators, and accidents involving plutonium-fueled or breeder reactors. Two publicized incidents involving nuclear weapons have occurred in the past three years: one in Spain and one at Thule, Greenland.

PHYSIOLOGY AND TOXICOLOGY OF PLUTONIUM

A brief review of a few physiological and toxicological properties of plutonium may be pertinent. It has been amply demonstrated that enough plutonium deposited in the tissues of an animal will produce neoplasia. When plutonium gains entry into the systemic circulation, it deposits preferentially in the skeleton and liver. Its relative deposition in the two

[1]This paper was presented as a part of the National Center for Radiological Health's Seminar Program on December 6, 1968 in Rockville, Maryland.

organs is dependent on valence state and degree of colloidal aggregation. The skeleton is considered the critical organ for systemically deposited plutonium. The equivalent of approximately 25 times the presently accepted maximum permissible body burden (0.04 μCi) for nuclear energy workers has been observed to produce osteogenic sarcoma in beagles after about 10 years when the accumulated average dose to the skeleton has reached ~ 80 rads (Utah project). Absorption of plutonium from the gastrointestinal tract is extremely low, perhaps no more than 0.05-0.002 percent in man subject, of course, to variation with chemical form, age, etc. Absorption through the unbroken skin may be considered zero for most practical purposes. Absorption rate from wounds is slow also, and material in tissue tends to encapsulate and remain at the site where it can produce a tumorigenic response. As little as 0.07 μCi of $^{239}PuO_2$ placed intradermally in rabbits was observed to produce a tumor. Inhalation now appears to be the predominant route of entry of plutonium into the systemic circulation. Absorption from the lung may vary from less than one percent of the amount deposited in the lung to as much as 10-15 percent, depending on chemical form, particle size, and a host of other variables. Of equal concern is the fact that a large fraction of the plutonium deposited in the lung is eliminated at a very slow rate (half time 1-4 years) and some is carried into the pulmonary lymph nodes where its elimination rate is even slower. Following inhalation exposure, particularly of insoluble compounds, the relative plutonium concentration in tissue in descending order is lymph nodes, lung, liver, skeleton. The persistence of this observation has created much concern about the choice of the critical organ when exposure is via inhalation. Inhalation toxicity studies at Battelle Northwest have shown the development of extensive pulmonary fibrosis and lung neoplasms in beagles with lung retention levels 100-500 times that amount required to deliver a lung average exposure rate of 300 mrem/wk. Two cases of primary neoplasia in the lymphatics have been observed.

Ecological uptake of plutonium would appear to be a second-order risk. The discrimination factor from soils to plants (conc/g of plant to conc/g soil) appears to be of the order of 10^{-4}-10^{-5} depending on plant species, soil type, chemical form of the plutonium, etc. Certain aquatic biota, however, may concentrate plutonium by a factor of 1000-3000.

The above discussion briefly summarizes the more important toxicological and physiological factors relevant to a consideration of the problem of large-area plutonium contamination.

SOME EXAMPLES OF LARGE-AREA PLUTONIUM CONTAMINATION

The first large-area plutonium contamination incident occurred in New Mexico in 1945 with the first test of a plutonium fission weapon. I give this for historical and nostalgic reasons, for it gives me some claim to being one of the world's first field monitors for large-area plutonium contamination. The "Fat Man," as some called it, was an all-plutonium device that contained considerably more plutonium than modern weapons. Several of the people who had helped build it felt it would surely be a dud. If so, its entire plutonium inventory would be spread downwind from the test site. I was given the job of heading a monitoring team of myself and a G.I. driver to investigate the distribution of the unfissioned material. Our portable alpha counter consisted of a small tank of methane, a rubber tube connecting it to a windowless methane flow proportional counter probe, a set of earphones, and a rate meter, all of which were fastened to a metal box provided with a suitcase handle and containing 70 pounds of batteries. The weapon was not a dud, however, and the unfissioned plutonium deposited in the area was below detectable limits. After crisscrossing the predicted fallout pattern for seven hours. we started home not once having heard a significant click in the earphones of our instrument. A few miles south of Belen, New Mexico, we came upon another government car with a flat tire. As a part of war-time austerity, government cars were not equipped with pumps and spare tires. After a short conference, the alpha probe was detached from its rubber tube and the methane tank

used to inflate the tire. Looking back over the past 25 years, I have the feeling this was my moment of greatness.

A second example involves worldwide contamination from plutonium produced by nuclear weapons testing prior to the atmospheric test ban treaty and reentry burnup of one ^{238}Pu thermoelectric generator in connection with a space mission failure. The total amount of plutonium contributed to the world environment to date may amount to about 500 kCi. Plutonium dispersed in this manner has been deposited essentially worldwide in accordance with the sophisticated models that have been developed for worldwide fallout in general. Plutonium indeed has been detected in human tissues, food, precipitation, and in the atmosphere at ground level and at altitude. The amounts in human tissues (primarily lung and liver) are at most a few pCi/kg. Much of this information comes from the fine efforts of the Public Health Service's own laboratories. At the present time these results are more significant to the demonstration of the extreme sensitivity of plutonium detection methods than they are to human health. This in no way belittles the importance of such measurements. On the contrary, assessment of the importance of future incidents may require knowledge of the situation prior to such incidents.

I will mention only two other examples: the one in Spain and the one at Thule, Greenland, which are more in context than the previous ones with the problem of large-area plutonium contamination as I visualize it in this presentation. Since you are perhaps already acquainted with many of the details of these incidents, I will mention only what I consider to be the more important general features of each. In Spain an aerial refueling explosion involving a B-52 bomber carrying four plutonium-bearing nuclear weapons and a KC-135 tanker occurred on January 16, 1966, 28,000 feet above the Mediterranean coastline near the Spanish village of Palomares. Two of the weapons were recovered intact, one from the ocean floor five miles offshore and one from a dry river bed near the village. Another one impacted on the very edge of the village on the downwind side. On impact the high-explosive component of the weapon detonated, blowing the weapon's plutonium inventory along with such soil and debris into the air. The prevailing 30-knot wind dispersed the cloud away from the village but down across the villagers' principal irrigated agricultural area. The major crops were tomatoes and alfalfa, which were about ready for harvest at the time. The fourth weapon impacted in a hillside about one mile upwind from the village.Its hign-explosive charge detonated also, and the plutonium-containing cloud drifted down a valley across more of their irrigated crops and through the northern one-third of the village. The village consisted of about 300 inhabitants. Homes were not highly contaminated, but some crop areas were contaminated to the extent of 1 mg/m^2 ($\sim$ 70 μCi/m^2) and greater.

Contamination contours were established and negotiations initiated to determine courses of action and decontamination levels. No official or realistic standards for courses of action and decontamination levels exist around which to base such negotiations. In the final agreement, all crops were stripped from the fields and destroyed where readings above 5 μg/m^2 were observed. All areas where the readings were between 5 and 500 μg/m^2 were plowed to a depth of at least 10 inches to lower the probability of resuspension of respirable plutonium oxide particles, and areas with readings greater than 500 μg/m^2 were stripped of top soil and the contaminated soil, debris, and vegetation returned to the United States. The top soil was removed from 5-1/2 acres and vegetation removed from 600 acres, which was subsequently plowed. Areas too rough to plow but contaminated to the extent of 50 μg/m^2 or greater were worked into the surface by hand.

On January 21, 1968, a B-52 with four plutonium-bearing nuclear weapons on board was attempting an emergency landing at Thule Air Force Base. At about 9000 feet over the base, the command was given to bail out. The abandoned plane circled in a northwesterly direction and crashed on the ice of North Star Bay (Danish territory) about 7½ miles from the west end of the Thule runway. The plane hit the three foot thick ice at a shallow angle ($\sim$15°) with the left wing

low ($\sim 60°$). The gross weight of the plane was about 410,000 pounds, of which about 225,000 pounds was fuel. The speed at impact was in excess of 500 knots. The shallow impact angle and mass and speed of the aircraft resulted in a great forward vector of momentum. When the high-explosive components of all four weapons detonated, the plutonium was blown out isotropically and impinged into the materials of the weapon and aircraft and blown into the splashing, burning fuel.The splashing, burning fuel and debris from the aircraft were catapulted along the surface ice, which was covered with about 8-10 inches of snow pack. When the burning fuel contacted the surface, the fire was soon extinguished, leaving a blackened refrozen crust on top of the snow pack. This black pattern was 300-400 feet wide and approximately 2200 feet long. The ice was completely shattered and disoriented at the impact point and sustained circular cracking out to a distance of about 100 yards in all directions. From momentum considerations and pattern on the snow pack, one would expect to find a large fraction of the plutonium trapped in the blackened crust. Indeed, this was found to be the case.

Actual contamination levels and contour values cannot be given at this time because of the desire of the Department of Defense to withhold quantitative information until a joint report including both U. S. and Danish investigations can be issued. In general respect, the ultimate disposition of the Thule incident was similar to that at Palomares even though the conditions were entirely different. Surface contamination contours were established, all contaminated debris and the blackened crust (~ 15 acres) were removed, confined ashore and subsequently shipped back to the United States for disposal. The crushed ice area containing a small fraction of the total plutonium inventory was covered with carbonized sand to induce melting prior to general breakup of the surrounding bay ice and, as in Spain, a follow-on ecological program was initiated. The overriding difference in conditions of the two incidents was one of difference in population density and habits. There is little point to contrasting these two incidents and their disposition. It would seem much more important to consider the problem had either occured in a suburb of Washington, D.C., or Omaha, Nebraska, or in a wheat field in Kansas. Weapons also are not the only potential source of plutonium contamination incidents. On a weight basis, with other factors the same, a ^{238}Pu incident would be worse by a factor of 270.

PRESENT PHYSICAL AND BIOLOGICAL BASIS FOR ACTION

The problem of plutonium contamination from noncritical nuclear weapons detonations was first presented in 1955. I co-authored the first naive reports attempting to evaluate the risk from such incidents. Conceptually, two elements of risk are involved. First is the risk of inhaling plutonium during cloud passage and deposition. If significant amounts are inhaled, it will impose both a systemic and a lung exposure risk. The probability of inhaling a significant amount is dependent on a variety of factors among which are source strength, dispersal force (pyrotechnic factors), cloud size, wind speed and other meteorological conditions, particle size (not only of the plutonium itself, but of the debris with which it is associated), and chemical form. It is interesting to consider that, practically speaking, little may be done about this element of risk as it is likely to have been imposed before any action can be taken. In this connection, it is important to monitor for fission products as soon as possible to establish the absence of any gamma-emitting radionuclides. In the event of criticality or fission product involvement, immediate action could be necessary. If plutonium alone is involved, immediate action is not critical. Under nominal conditions, it appears that the risk associated with lifetime occupancy of a contaminated area may not be much greater than that associated with cloud passage and deposition. If this be true, immediate action is not paramount.

The second element of risk pertains to permanent occupancy of an area that has been contaminated. Practically speaking, it is here that something could be done if considered prudent or necessary. If practical guide lines

of prudence or necessity were available, one could evacuate the population, decontaminate the area, initiate follow-on ecological studies, or do all or nothing depending on the circumstances.

Our early considerations of the noncritical weapons detonation problem involved a mathematical gymnastic based largely on assumptions, backed up by remotely applicable data regardless of source, and the philosophy and recommendations of the NCRP. The approach to the first element of risk was to calculate lung deposition (based on the NCRP lung model at the time) from source strength, cloud size and concentration (derived from explosive yield), Stokes law, and wind speed. It was further assumed that for a once-in-a-lifetime exposure the lung burden required to deliver an average dose rate of 300 mrem/wk to 1000 g of lung tissue was an acceptable risk to a member of the general public. The approach to estimating the second element of risk (that of continuous occupancy of a contaminated area) was to apply resuspension and attenuation factors to the surface deposition level. The resuspension factor was defined as the ratio of the air concentration above a contaminated surface (in $\mu g/m^3$) to the surface deposition level in $\mu g/m^2$. The permissible surface deposition level was then calculated for various values of the resuspension factor assuming a maximum permissible lung burden of 0.02 μCi and a maximum permissible systemic burden of 0.04 μCi at the end of a 70-year lifetime occupancy with an attenuation rate of a factor of 10/year for the resuspension factor throughout the entire 70-year period. Just as a matter of interest, the values for acceptable surface deposition levels for lifetime occupancy derived from these early considerations are given in Table 1. The conclusion drawn was that perhaps an area contaminated initially to the extent of 100 $\mu g/m^2$ (7.0 μ Ci/m^2) of $^{239}PuO_2$ was safely inhabitable for a lifetime without decontamination. It was pointed out, however, that the principal weakness in the approach was the inadequacy of existing data on resuspension and attenuation factors, and it was recommended that considerable effort be made to obtain more data on these factors under a variety of meteorological and physical conditions. Of interest also (at least to me) was the fact that a member of the Danish scientific team used identically the same approach (with a resuspension factor of 10^{-3}) during the Thule deliberations.

TABLE 1. Maximum Permissible Initial Surface Concentration Levels for Lifetime Occupancy

Conditions of Resuspension	Resuspension Factor	Permissible Initial Surface Contamination Level ($\mu g/m^2$)
Vehicular traffic (Nevada)	7×10^{-5}	10
British rescue operations (closed space)	4×10^{-5}	20
Dirty rural, suburban, and metropolitan air	7×10^{-6}	100
British rescue operations (in the open)	2×10^{-6}	360

Obviously, the greatest physical weakness in this approach (which currently may be the only one) still lies in the fact that the resuspension factor depends on so many variables that it undoubtedly will be different in every situation (as will the attenuation factor) and may vary by as much as 10^5. Subsequent tests in Nevada (Plumbbob, Roller Coaster) suggested that an area initially contaminated to the extent of 70 μCi/m^2 (1000 μg/m^2 of $^{239}PuO_2$) or even greater might be safely inhabitable and produced volumes of detailed data on a number of physical factors pertinent to the general problem. These involve particle size distributions, cloud phenomena, dependence of air concentrations and deposition levels on meteorological conditions, time dependence of resuspension, etc. Unfortunately, applications of these data to the general problem are drastically complicated by the fact that they are biased by the desert conditions under which such tests must be conducted.

If presently the physical basis for action seems inadequate or hopeless, the biological basis seems even more so. Let us briefly review the basic standards of maximum permissible internal exposure. Two somewhat different basic criteria commonly are used in deriving maximum permissible internal exposures:

> **for bone-seeking radionuclides such as ^{239}Pu, ^{90}Sr, etc., that emit significant amounts of particulate radiation, the derivation is based on a comparison with ^{226}Ra and daughter products**
>
> **for other tissues involving the same or other nuclides (with some exceptions), the derivation is based on a comparison with x radiation.**

The expressions are:

(a) Comparison with ^{226}Ra

$$q = \frac{q(Ra) \times f_2(Ra) \times [\Sigma E(QF)_\eta](Ra)}{f_2[\Sigma E(QF)_\eta]}$$

(b) Comparison with x-ray

$$q = \frac{2.8 \times 10^{-3}\ mW}{f_2[\Sigma E(QF)_\eta]},$$

in which q is the maximum permissible body burden (μCi), f_2 is the fraction of the body burden that is in the critical organ, Σ E(QF) is the sum of the energies of all emissions weighted individually by the appropriate quality factor (QF), and η (the factor of ignorance) is a factor for nonhomogeneity of distribution within the critical organ or anything required to make calculation and biological observation reasonably compatible. In the lower expression, m is the mass of the critical organ (g), and W is the allowable x-ray exposure rate in rem/wk for the tissue in question (for most tissues 0.3). Estimation of the systemic maximum permissible body burden for ^{238}Pu and ^{239}Pu from expression (a) gives 0.04 μCi (40 nCi) based on the skeleton as the critical organ. Estimation of the maximum permissible burden using expression (b) and the lung as the critical organ gives 16 nCi. Using 10 g of pulmonary lymphoid tissue as the critical organ and f_2 = 0.5, the maximum permissible body burden would be 0.32 nCi. Table 2 shows the activity of $^{238}PuO_2$ and $^{239}PuO_2$ particles in terms of nCi/particle and number of particles equivalent to 16 nCi as a function of particle diameter. If, according to custom, the above values are lowered by a factor of 10 to apply to population groups in the public domain, it would appear that the present method of assessing public risk is leading to deep trouble, particularly where high specific-activity materials such as ^{238}Pu are involved. Table 2 suggests that the public maximum permissible level for $^{238}PuO_2$ and $^{239}PuO_2$ based on the lung as the critical organ would be about 20 and 5700 1-micron diameter particles, respectively; based on the respiratory lymph nodes, the respective maximum permissible levels would be 0.4 and 115 1-micron diameter particles. Only three 2-micron diameter particles of $^{239}PuO_2$ would constitute an overexposure, assuming the total lung as the critical organ, even though there would be only three

TABLE 2. Activity of $^{238}PuO_2$ and $^{239}PuO_2$ Particles as a Function of Particle Diameter

Diameter (μ)	$^{238}PuO_2$		$^{239}PuO_2$	
	nCi/particle	Particles/16 nCi	nCi/particle	Particles/16 nCi
0.01	8.0×10^{-8}	2.0×10^{8}	2.8×10^{-10}	5.6×10^{10}
0.02	6.4×10^{-7}	2.5×10^{7}	2.3×10^{-9}	7.0×10^{9}
0.04	5.1×10^{-6}	3.1×10^{6}	1.8×10^{-8}	8.9×10^{8}
0.07	2.8×10^{-5}	5.7×10^{5}	9.7×10^{-8}	1.6×10^{8}
0.1	8.0×10^{-5}	2.0×10^{5}	2.8×10^{-7}	5.6×10^{7}
0.2	6.4×10^{-4}	2.5×10^{4}	2.3×10^{-6}	7.0×10^{6}
0.4	5.1×10^{-3}	3.1×10^{3}	1.8×10^{-5}	8.9×10^{5}
0.7	2.8×10^{-2}	5.7×10^{2}	9.7×10^{-5}	1.6×10^{5}
1.0[a]	8.0×10^{-2}	2.0×10^{2}	2.8×10^{-4}	5.6×10^{4}
2.0	6.4×10^{-1}	2.5×10^{1}	2.3×10^{-3}	7.0×10^{3}
4.0	5.1×10^{0}	3.1×10^{0}	1.8×10^{-2}	8.9×10^{2}
7.0	2.8×10^{1}	0.57	9.7×10^{-2}	1.6×10^{2}
10.0	8.0×10^{1}	0.2	2.8×10^{-1}	5.6×10^{1}

[a] Dose rate at surface of $^{238}PuO_2$ particle: alpha 10^5 rad/hr, gamma 22 rad/hr.

very small discrete foci of radiation exposure. It would appear highly improbable indeed that total energy released (most of which is from alpha particles) in a small volume of tissue, multiplied by an appropriate QF and averaged over 1000 g of lung tissue, could be an adequate biological basis for public risk assessment from a large-area plutonium contamination incident. Under these exposure conditions, the obvious difficulty is the ignorance factor (η). At Los Alamos we are engaged again in some more mathematical gymnastics based largely on assumptions and an occasional bit of remotely relevant data. We are trying to develop probabilistic models of risk assessment based on the number and size of particles in the lung and probability of lung tumor as a function of the number of cells at risk. The same approach is being applied to the risk of skin tumors from contact with fissioned $^{235}UC_2$ particles as might be ejected from nuclear rocket propulsion reactors. My confidence in what we have done with this approach to date is no greater (or even less, if possible) than it is in the organ-dose averaging approach. Animal experiments can be designed, however, that would verify the approach and provide the basis for meaningful modifications. We have already conducted preliminary experiments and are hopeful of starting large-scale animal studies in the near future. We hope to study tissue response to individual spherical particles of $^{238}PuO_2$ and $^{239}PuO_2$ of different sizes and observe lung tumor incidence as a function of dose, calculated cells at risk, and amount of fibrotic response. Until more meaningful approaches are developed for evaluation of risk from the high specific-activity particle, there is little alternative but to continue trying to relate exposure situations to current NCRP recommendations.

SOME INTERIM SUGGESTIONS

I once read a book "Something in Return," the essence of which was that one does not destroy a way of life without offering something in return. I stated earlier that no official or realistic standards for decontamination levels and courses of action exist for large-area plutonium contamination incidents even to

provide a basis for negotiations. I have suggested also that presently there does not appear to be either an adequate physical or biological basis on which to establish standards for a course of action in the event a sizable population group is involved in a plutonium contamination incident. Furthermore, no single set of standards may be hoped for that would apply specifically to any and all situations. All this pessimism, however, does not mean interim effort cannot lead to considerable improvement in the handling of such a contamination incident should one occur.

1. Even though the biological basis for risk evaluation is inadequate, serious consideration might be given to the development of guides for minimal acceptable action in a standard or likely average situation with respect to population density, resuspension probability, etc., which could be adjusted by knowledgeable people and responsible agencies to apply to the actual situation when it occurs. Guides for minimal acceptable action should be based on the best current approach to evaluation of the real risk to a population group. The data from projects Plumbbob and Roller Coaster might be organized with the standard situation specifically in mind. A concerted effort in this direction may show that the physical basis for formulating action guides is not as inadequate as it might appear.

2. Hypothetical exercises could be programmed (in the manner done by Civil Defense) in which the Thule, Spanish, and Nevada contamination patterns are superimposed on the standard situation, a suburb of Washington, D.C., or Omaha, Nebraska, or a wheat field in Kansas. Scaling factors could be developed for various source strengths, meteorological conditions, etc. Competent people for doing such exercises already exist; even I could suggest specific individuals.

3. Mor active support and encouragement could be given to research programmatically oriented toward establishing a realistic biological basis for evaluating the hazards from highly radioactive particulates. Agencies that may choose to support such research should appreciate the fact that it will be neither easy nor cheap. What is required is a biological basis for a probabilistic evaluation of the long-term or lifetime risk, and he who seeks a long-term answer should be prepared to spend a long time seeking. Not only is such effort needed for plutonium alone, but as a basis for controlling isotopes of other transuranic elements as well. If again we can believe alchemist Seaborg (and so far he has given us no reason to doubt him), "This production program (of transuranic elements) will ensure a steady supply of these elements to permit a vigorous program of expanded research and exploitation of their unique and useful propeerties."

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THE PROBLEM OF LARGE-AREA PLUTONIUM CONTAMINATION

U.S. Department of Health, Education and Welfare, Consumer Protection and Environmental Health Service, Environmental Control Administration, Bureau of Radiological Health (1969)

ABSTRACT: Although no plutonium contamination incidents have occured in the public domain that have imposed serious risk on a population group, the probability that such might occur is likely to increase with the current increasing production and use of plutonium isotopes. At present there does not appear to be either an adequate physical or biological basis on which to establish standards for a course of action in the event a sizeable population group is exposed to a contamination incident involving this potentially hazardous material. In view of two recent experiences, the hope that a single set of standards can be developed that will be

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THE PROBLEM OF LARGE-AREA PLUTONIUM CONTAMINATION

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ABSTRACT: Although no plutonium contamination incidents have occurred in the public domain that have imposed serious risk on a population group, the probability that such might occur is likely to increase with the current increasing production and use of plutonium isotopes. At present there does not appear to be either an adequate physical or biological basis on which to establish standards for a course of action in the event a sizeable population group is exposed to a contamination incident involving this potentially hazardous material. In view of two recent experiences, the hope that a single set of standards can be developed that will be

ACCESSION NO.

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